ERDC/CERL TR-16-9

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
INNOVATIVE SOLUTIONS for a safer, better world

Adaptation Strategies for Training Lands and Ranges at Fort Leonard Wood, MO

Dick L. Gebhart, Ryan R. Busby, Andrew M. Hamblin, Annette L. Stumpf, and Susan J. Bevelheimer

July 2016

The U.S. Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at http://acwc.sdp.sirsi.net/client/default.

ERDC/CERL TR-16-9
July 2016

Adaptation Strategies for Training Lands and Ranges at Fort Leonard Wood, MO

Dick L. Gebhart, Ryan R. Busby, Andrew M. Hamblin, Annette L. Stumpf, and Susan J. Bevelheimer

U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
2902 Newmark Dr.
Champaign, IL 61824

Final Report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Garrison Fort Leonard Wood

Abstract

In the United States and its territories, the Department of Army manages approximately 11 million acres of land for military use. The repeated and consumptive use of these lands for military training and testing activities, which is unique to the U.S. Department of Defense (DoD), creates a significant land management challenge. Superimposed upon these types of disturbance-related impacts are climate change scenarios that predict warming and greater climatic variability for the foreseeable future, including more frequent and severe droughts and intense storm events. This work identified and described several key planning and management activities that can be implemented in the face of a changing climate to ensure that training and testing ranges at Fort Leonard Wood, MO will continue to provide sustainable, realistic, and cost effective training opportunities for the warfighter well into the future.

Contents

Illustrations

Figures

Preface

This study was conducted for the Plans, Analysis, and Integration Office (PAIO) at U.S. Army Garrison Fort Leonard Wood under Military Interdepartmental Purchase Request (MIPR) No. 10599341 "Net Zero Planning for Fort Leonard Wood, MO," dated 23 September 2014. The technical monitor was Mark Premont, Director, Fort Leonard Wood PAIO.

The work was performed by the Energy Branch (CFE) and the Engineering Process Branch (CF-N) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). The CERL Principal Investigators were Susan Bevelheimer and Annette Stumpf. At the time of publication, Charles G Schroeder was Chief, CEERD-CFN; and Donald K. Hicks was Chief, CEERD-CF. At the time of publication, Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

COL Bryan S. Green was Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

THIS PAGE INTENTIONALLY LEFT BLANK

1 Introduction

1.1 Background

In the United States and its territories, the Department of Army manages approximately 11 million acres of land for military use (DoD 2013). The repeated and consumptive use of these lands for military training and testing activities, which is unique to the U.S. Department of Defense (DoD), creates a significant land management challenge. Repeated training disturbances can displace or eliminate native species and adversely affect ecosystem integrity and function by altering water, energy, nutrient, and disturbance cycles, which in turn, can cause loss of biodiversity, increased soil erosion, and degradation of threatened and endangered species (TES) habitat.

Superimposed upon these types of disturbance-related impacts are climate change scenarios that predict warming and greater climatic variability for the foreseeable future, including more frequent and severe droughts and intense storm events. This combination of factors suggests that Army training and testing range management for sustainable and continued use over the next 20-75 years will increase in both scope and complexity. This work was undertaken to explore several key planning and management activities that can be implemented in the face of a changing climate to ensure that training and testing ranges at Fort Leonard Wood, MO will continue to provide sustainable, realistic, and cost effective training opportunities for the warfighter well into the future.

1.2 Objective

The objective of this work was to highlight several key planning and management activities that can be implemented in the face of a changing climate to ensure that training and testing ranges at Fort Leonard Wood, MO, continue to provide sustainable, realistic, and cost effective training opportunities for the warfighter well into the future.

1.3 Approach

A literature search was performed to review current research in the areas of climate change and land management practices specifically related to the Fort Leonard Wood, MO geographical area. Results most pertinent to training and testing range management at Fort Leonard Wood were described and summarized.

1.4 Scope

Although this work focused on facilities at Fort Leonard Wood, MO, the results of this effort are broadly applicable to many DoD installations in the Continental United States.

2 Climate Change Projections

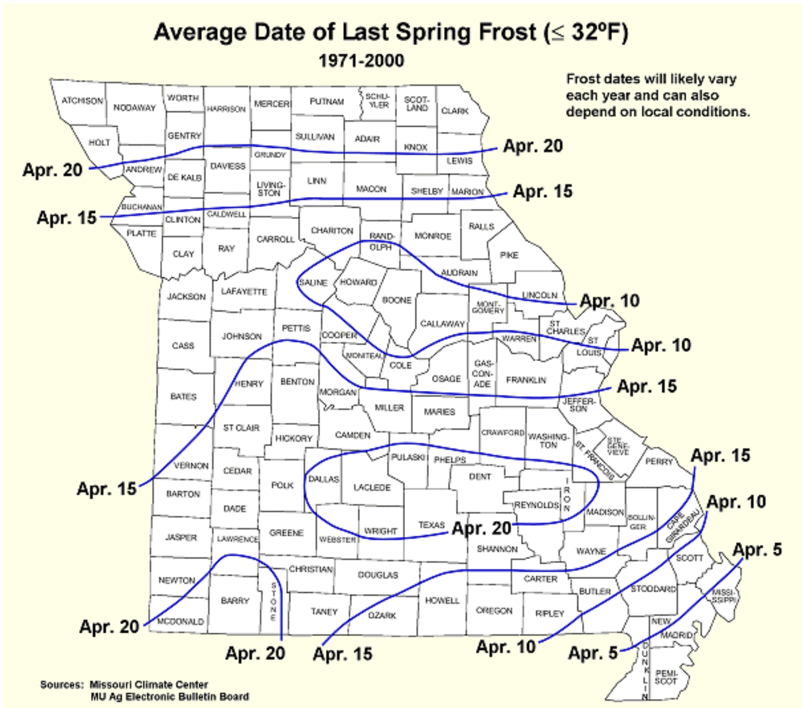
While temperature and precipitation fluctuations are primary drivers of vegetation quality and fire risk, predictive capabilities for these trends are difficult for any particular location. Thus, a more accurate climate projection is presented to provide a general indication of the degree of change that can be expected. Based on historical records, the frost free date for Pulaski County is April 20, while the first frost date is October 15 (Figure 2-1), a growing season of 186 days.

By 2050, these dates are estimated to be April 15 and October 27, respectively; an increase in the growing season by 17 days (similar to Fayetteville, AR, currently). By 2090, these dates are estimated to be April 10 and November 11, respectively; an increase in the growing season by an additional 36 days, or almost a 1-month increase compared to the current growing season (Figure 2-1), similar to Fort Smith, AR, and Oklahoma City, OK, currently.

These increases, while seemingly insignificant now, will cause changes to the vegetation composition of Fort Leonard Wood over time. Some species with a southern range limit near Fort Leonard Wood will disappear, while species with a northern range limit near Fort Leonard Wood will appear. One can expect both positive and negative changes associated with these migrations. Some important species may become less common, some new species may become important for land rehabilitation, and new invasive and nuisance species may appear. The greatest impact of these changes will be a shift in the available windows with which to conduct land rehabilitation.

The following sections discuss these aspects in greater detail.

Figure 2-1. Projections are average values taken from six General Circulation Models (GCMs) under scenario RCP8.5 (Representative [CO2] Concentration Pathway), using the daily bias-correction/constructed analogs temperature minimum data, and averaged first/last days over the 10 years surrounding each projected date (2045-2055 for 2050 and 2085-2095 for 2090).



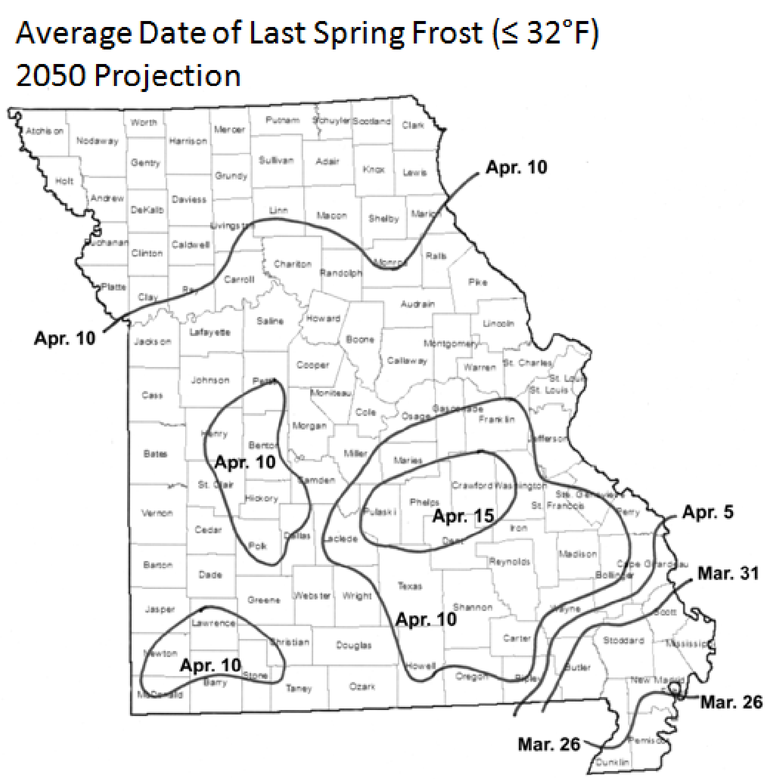
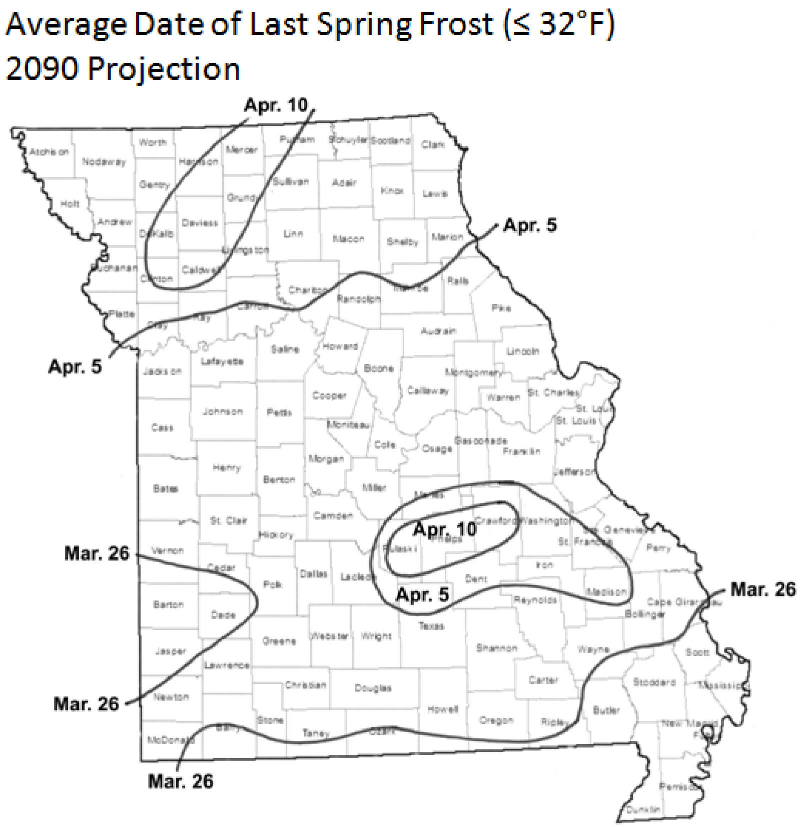


Figure 2-1. (Cont'd).



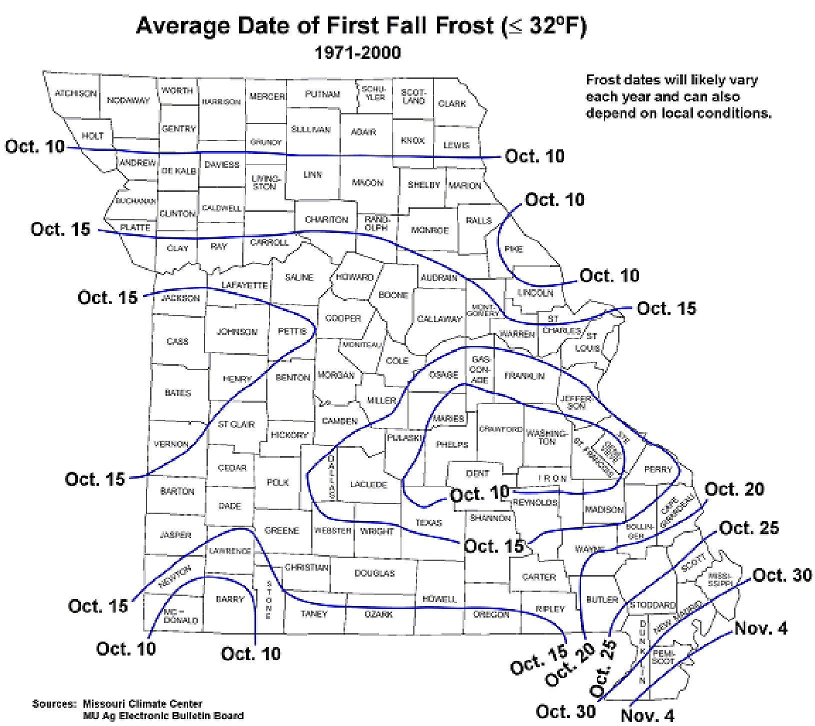
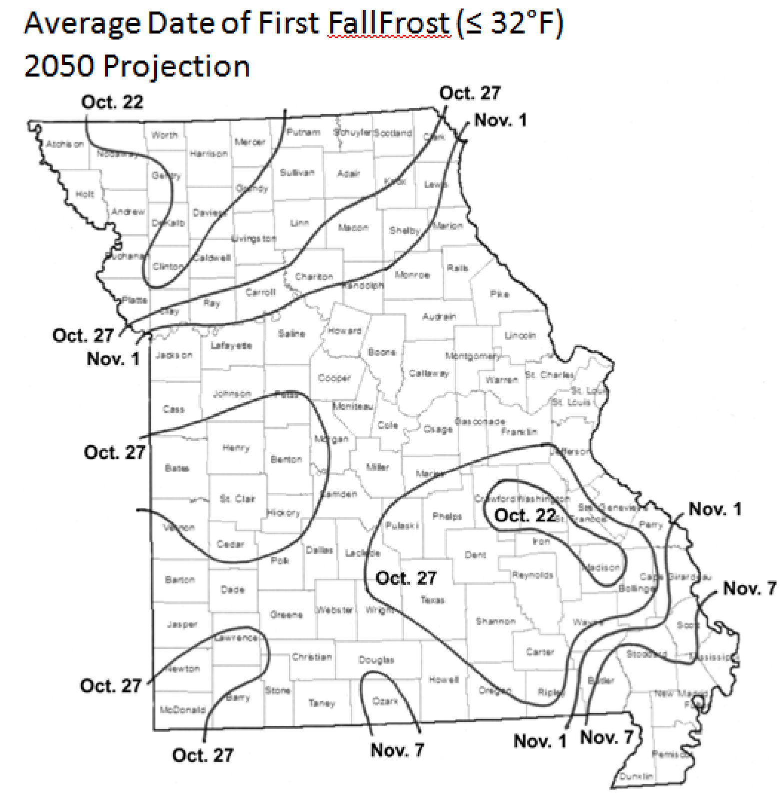
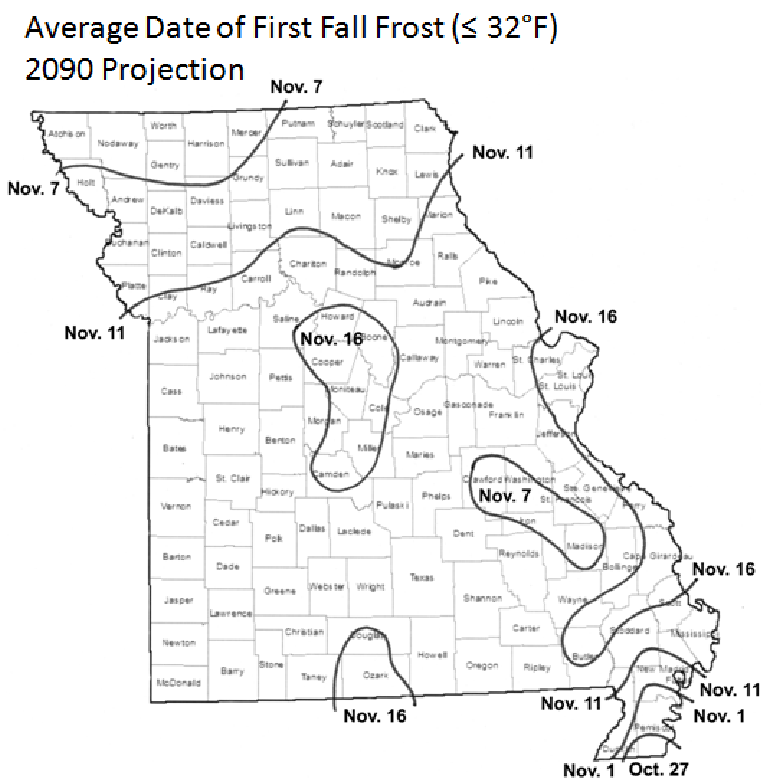


Figure 2-1. (Cont'd).





3 Adaptive Planning

From a training range management perspective, one of the more important potential changes associated with longer growing seasons are increased fire risk and frequency as earlier springs will promote greater biomass accumulation, thereby extending and increasing the severity of fire season (Pechony and Shindell 2010). Most wildfires in central Missouri occur during the hottest, driest portion of the year (Westerling et al. 2003), and the size of the area burned in any given year is strongly correlated with the Palmer drought severity index which is expected to increase with increasing length of growing season.

One of the greatest historical and future challenges associated with the Integrated Training Area Management (ITAM) and Land Rehabilitation and Maintenance (LRAM) programs is the balance between scheduling and use of training ranges, the level of training-related damages, downtime for range repair and maintenance, and funding levels to accommodate range maintenance and repair activities necessary to ensure sustainable and realistic training opportunities for the foreseeable future. This balancing act is not unique to Fort Leonard Wood, but it is important to highlight some of the programmatic and funding issues that will continue to have far greater impacts on range development, use, maintenance, and future sustainability than any potential long-term changes in climate. Without considering these programmatic challenges, recommendations for the more practical aspects of LRAM such as organic matter conservation and seed/species selection, for example, are only secondary.

Communication between Range Control/ITAM, the Garrison Commander, and the Natural Resources group responsible for performing LRAM activities is paramount. No amount of planning and preparation can prevent a wildfire, and immediate response mechanisms need to be in place to address such unforeseen emergencies. Frequent communication regarding training activities, weather, condition of vegetation and other natural resources attributes allows each party to assess the potential for catastrophic damage within the context of continued military training and develop contingency plans for dealing with unforeseen events.

Many natural resources management activities such as firebreak management, emergency seeding, and mowing are time and weather dependent and have short windows of opportunity for completion. Current contracting for these types of work require long lead times and frequently the work cannot be accomplished when it is needed. There also appears to be some inflexibility in times, days, and personnel allowed access to ranges to perform routine maintenance and repair. Many of these routine repair and maintenance activities are specifically designed to reduce the likelihood of wildfires and accelerated erosion and, as such, should be afforded scheduling flexibility and priority.

As part of each training event scheduled by individual units through range control, some mechanism for contributing to a dedicated “Green Fund” should be developed. This “Green Fund” could be based on anticipated Maneuver Impact Miles (MIMs) or some other metric that allows funds to be provided directly by the unit conducting the training and deposited for use to cover LRAM fixed costs such as seed, organic matter, mowing, earthwork, etc. A dedicated fund that could only be used for LRAM activities would partially eliminate the need for lengthy and contorted contracting actions that seldom meet the time and weather sensitive needs of LRAM activities designed to reduce risk.

3.1 Organic matter conservation

Most training lands, including those at Fort Leonard Wood, are often highly eroded as a result of recurring and destructive training activities and continually incur significant losses of topsoil, organic matter, and nutrients that accelerate ecological degradation. The benefits of organic matter content to soils that are sandy textured, have poor water holding capacity, and/or are highly eroded or compacted are well known. Any agronomic practice that conserves or improves organic matter content improves water holding capacity and the moisture release dynamics of soils (Turner et al. 1994, Giusquiani et al. 1995), thereby supporting more desirable plant communities that are tolerant of training disturbances (Watts et al. 2012a,b). As the climate becomes warmer with more frequent and severe droughts, the importance of maintaining or improving soil organic matter content becomes even more critical.

As indicated above, military maneuver training frequently results in heavily compacted soils and organic matter applications nearly always decrease bulk density (Turner et al. 1994, Giusquiani et al. 1995, Pagliai and Vittori-Antisari 1993), thereby minimizing erosion risk and improving water infiltration, porosity, and storage for plant use as the growing season progresses (Zhang et al. 1997). Organic matter sources can be as simple as chopped, shredded, mowed, or composted vegetative material that would include wood chips and sawdust. Ideally, these are applied and mixed into the soil during some type of re-seeding or land rehabilitation event as discussed below, but they can also be surface applied to areas of concern. From a climate change and adaptive planning perspective, the addition of organic matter as part of any routine training range rehabilitation and maintenance activity is probably one of the most effective ways to ameliorate warmer temperatures and more frequent drought impacts associated climate change (Polley et al. 2013).

Rehabilitating degraded military training and testing sites where soils typically lack organic matter and favorable physical and chemical properties conducive to establishing and supporting perennial plant communities, requires significant inputs of organic amendments to improve the probability for success and sustainable future use, especially since organic matter is one of the most effective ways to ameliorate the impacts associated climate change (Polley et al. 2013). Minimum organic matter application rates should be in the range of 10 to 15 tons per acre which translates to a layer about 0.25 in. deep over the entire acre (McConnell et al. 1993).

A review of rates used in experimental studies suggest that applications of organic matter between 10 and 30 tons per acre provide observable improvements in soil physical and chemical properties without significant phytotoxic effects (McConnell et al. 1993). Application rates for sandy soils can be doubled without significant concern for negative impacts (McConnell et al. 1993, Busby et al. 2006, Watts et al. 2012a,b). Application rates beyond 80 to 100 tons per acre should be split and should always be planned based on a soil and compost nutrient and heavy metal analyses to make sure that it is safe to apply organic matter at those rates. Studies by Watts et al. (2012a) and Mamo et al. (1998) have indicated that the benefits of a single heavy application rate can still be observed 5 years after the initial application.

Because most organic matter applications on degraded training ranges and maneuver areas are usually followed by some type of revegetation effort, it is important to make sure the organic material is evenly applied and subsequently incorporated before seeding perennial grass species. This is most effectively accomplished with a commercial manure spreader, however, dump trucks or front end loaders can also be used. Using the 0.25-in. organic matter depth as a guide equivalent to a rate of 10-15 tons per acre, calibrate the spreading equipment to achieve the desired application rate, recognizing that some variability in rate across the area to be treated is perfectly acceptable. After the organic matter has been spread, it should be incorporated into the soil using a disk plow if possible to a depth of 4-6 in. This provides the best possible seedbed for subsequently seeding grasses and minimizes the probability that the organic material will be removed from the site via wind or water erosion.

3.2 Seed and species selection

Selection of seed does not require significant alteration at present. However, some alternatives are provided for consideration for complementing existing mixes or replacing specific components. Currently, timothy, fescue, and clover are primarily seeded for fire breaks. Wheat was historically used but its effectiveness has lessened due to the inability to mow it as needed for proper maintenance. Other fire break species currently used are cowpeas and buckwheat. Timothy, a C3 cool-season grass (Figure 3-1), is used because it tolerates hotter and drier conditions than most C3 grasses and is able to function similarly to C4 warm-season grasses.

Figure 3-1. Timothy, a C3 cool-season grass that tolerates hot, dry conditions, is useful for planting in fire breaks.

Another potential cool-season species that functions as a warm-season grass is orchardgrass (*Dactylis glomerata*) (Figure 3-2). Both Timothy and Orchardgrass are important in terms of adapted plants for a hotter, drier climate in that they both can begin growth earlier and maintain vegetative productivity later into the growing season when most cool-season grasses would begin senescing, thereby creating a late season fire hazard. A potential alternative cover crop is cup plant (*Silphium perfoliatum*), a native forb that has shown potential as a forage crop in the Midwest (Stanfort 1990, Albrecht and Goldstein 1997). *Tridens flavus*, a native perennial warm season grass, could be used as an alternative or substitute for the warm season grass component. *Paspalum floridanum*, a native perennial warm season grass currently with limited seed availability, could also be used in this capacity.

Figure 3-2. Orchardgrass, a C3 cool-season grass, is useful for planting in fire breaks.

3.3 Specialized seeding for rehabilitation of damaged training ranges

3.3.1 Hydroseeding

Hydroseeding (Figure 3-3) should not be used over large, flat areas, but rather is much more effective on steep slopes or inaccessible areas such as pond and wetland edges. For flat, inaccessible areas, broadcast seeding should be used. For hydroseeding, site preparation and finishing are paramount to successful establishment. However, due to equipment and material requirements, road access is necessary, which significantly reduces the utility of hydroseeding. Hydroseeding should not be used on dry, dusty soils, or during hot, dry periods. Hydroseeding should not be performed when wind speed exceeds 15 mph or gusts affect seed placement.

Figure 3-3. Hydroseeding is most useful for steep slopes or inaccessible areas rather than flat terrain.

Hydroseeding should be conducted with a fan-type nozzle with 500 gallons of water/ac and 75 lb hydromulch per 500 gallons of water (MN DOT 2007). If hydraulic soil stabilizers are used for mulch, the stabilizer should be applied as a separate operation following seeding to ensure seed contacts soil directly. Hydroseeding prairie plants is not recommended, as it does not meet the requirement for firm seed to soil contact. However, hydroseeding prairie can be successful if done in the fall with minimum amount of carrier and no tackifier. For hydroseeding, seed should not be added to the hydro-seeder tank more than 1 hour before seeding (MN DOT 2007). Hydroseeders should be emptied within 1 hour of adding seed, and any remaining seed should be disposed of.

3.3.2 Broadcast seeding

On areas smaller that are not on steep slopes but are inaccessible to equipment, broadcast seeding should be used. Seed should be installed evenly with a cyclone seeder equipped with an effective agitator to ensure constant mixing of seed, and mulched with weed free mulch if possible.

Following any seeding (including hydroseeding), sites should be harrowed or raked, cultipacked, mulched at a rate of 2 tons/ac and disc-anchored. Straw mulch should be spread at a rate of 2 tons/ac; hay mulch should be spread at a rate of 3 tons/ac. A mulch tiller should be used for crimping mulch into the topsoil, not a disc. A disc is not a mulch tiller, and will bury the mulch rather than pressing it into the soil. For native vegetation, seeded sites should be mulched with weed-free grain or prairie hay mulch at a rate of 2 tons/ac and disc anchored.

3.4 Standard seeding practices for rehabilitation of damaged training ranges

No seeding should be conducted in windy weather, or when the ground is frozen (unless dormant seeding), wet, or otherwise untillable. Germination only occurs when soil temperatures and moisture are adequate. Seed is most vulnerable to drought and freezing when it has just germinated. If planting late in the season, know when the first killing frost normally occurs, and weigh the risks of late season planting.

As much as 90% of seeding failures are due to dry soil (WI DOT 2009). Once seeds germinate, the top inch of soil should be maintained with adequate moisture until vegetation is well established. Most vegetation requires ½-in. of rainfall within the initial 7-day period following germination for adequate establishment. If water is necessary for establishment of seeded areas, it should be applied using a spray that will not dislodge mulch material. A rate of 13,000 gallons/ac split into two applications spread over 7 days should be enough to ensure establishment.

3.4.1 Drill seeding

On areas greater than 1 acre in size, drill seeding should be used (Figure 3-4). The seedbed should be firmed before seeding any native vegetation. Seed should be installed with a drop seeder equipped with a cultipacker and mulched. For seeding native vegetation, a native grass, or rangeland drill should be used that is capable of metering the seed boxes and uniformly mixing the seed. Rangeland drills should have three seed boxes: a grain box for large, non-bearded seeds of lawn-type grasses and cover crop species, a native seed box with pick fingers for adequate placement of bearded seeds such as native warm season grasses, and a fine seed box for small seeds such as wildflowers and other forbs. Each box should be calibrated independently from other boxes, and a press wheel should be mounted on the rear of each drop tube to firm soil over seed. As an alternative, each seed type may be seeded separately, with recalibration of the drill for each effort. Native grasses should be drilled with no less than two passes in different directions, with seed split evenly between passes.

Figure 3-4. Drill seeding can be used for areas larger than one-acre in size.

General seed mixes should be planted to a depth of ¼ in. Large and/or fluffy seeds should be planted at a depth of ¼ to ½ in., lightly covered with soil through raking or harrowing, and small seeds should be scattered on the soil surface. Seed of warm season grasses and forbs should not be covered more than ⅛ inch deep; all other seed should not be covered more than ½ in. deep. Cover crops should be seeded with a grain drill at a depth of ¼ to ½ in., or broadcast, harrowed or raked, and mulched using weed free grain straw or prairie hay at a rate of 2 tons per acre and disc-anchored.

Nurse crops are more useful to prairie planting in the fall to stabilize soil, and should be used at a higher rate in fall (15 lb/ac annual rye, 128 lb/ac oats) as in the spring (5 lb/ac annual rye, 64 lb/ac oats). Cover crops should be selected to provide for maximum short term cover immediately after they are sown. Minimum germination temperatures should aid in selection of cover crops for different seeding dates. Wheat and annual ryegrass germinate at a minimum temperature of around 40 °F, oats germinates at a minimum temperature around 45 °F, and sudangrass-sorghum germinates at a minimum temperature around 60 °F (Undersander et al. 1990, Pathak et al. 2012). Sudangrass produces significant biomass in summer, achieving an average of 1 ft in height after 3 to 4 weeks, 2 ft around 7 weeks, and 3 ft around 9 to 10 weeks in plantings across Illinois (Maughan 2011). Soybean requires a minimum germination temperature around 60 °F (Pathak et al. 2012). Ideal germination temperatures are usually around 10 °F greater than the minimum germination temperatures.

3.4.2 Dormant (frost and snow) seeding

Because many native species have specific requirements to break dormancy (stratification, scarification, etc.), fall seeding naturally meets these requirements. Further, as climate change causes planting windows to fluctuate, dormant seeding provides a significant additional window to ensure proper seeding is obtained but does not require ideal germination conditions to occur immediately after seeding. Additionally, if seeding over existing vegetation, fall seeding allows better seed/soil contact through the movement of soil during freeze/thaw cycles. Dormant seeding is defined as occurring when soil temperatures are consistently below 53 °F (WI DOT 2012) or when soil temperatures at a depth of 1 in. fall below 40 °F (MN DOT 2005).

Frost seeding uses natural cold, moist cycles for stratification, and uses natural freeze/thaw cycles to provide good seed-soil contact (Morrison 2009). Because native plant species are most sensitive to drought and freezing temperatures when in the seedling stage, care must be taken not to conduct frost seeding too early. Minimum germination temperatures for most native species is lacking, but for studied species (both grass and forb), appears to be around 59 °F (McGraw et al. 2003, Seepaul et al. 2011). Soil should be prepared before soil freezing.

In the current Fort Leonard Wood climate, snow seeding (Figure 3-5) is performed during thawing days in February and March. Snow seeding works best on soft, thin snow, as hard, thick snow can allow seed to blow across it or wash seed away if it melts rapidly. Hand seeding or a cyclone seeder should be used for frost or snow seeding (Morrison 2009). An inert material, such as dark colored husks or sand, should be mixed with seed to identify where seed is spread and to quickly melt the snow around seeds so they sink into the snow and are not visible to predators. Fertilizer should not be placed on frozen or snow covered soil.

Figure 3-5. Broadcast seeding into snow by hand or with a cyclone spreader in late Winter or early Spring can be an effective dormant seeding method

3.5 Recruitment of edge vegetation

All plant species have characteristic geographic distributions based on growth form, photosynthetic pathway, drought tolerance, rooting characteristics, climatic/geologic conditions, etc. Some individuals from these plant species occupy landscape positions near the very edge of that given species geographic distribution, and as such are referred to as edge species or edge plants. From a climate change adaptation planning perspective, it is important to note that edge plants can occur on both a macro- (geographic) and micro-scale (landscape), suggesting that even edge individuals on a given training area may have greater capacity for adapting to changing climatic and edaphic conditions than individuals in the center of the training area. Individual plants of a given species that occupy sites near the very edge of their distribution often have ecophysiological characteristics that may be more or less well developed than those of individuals near the center of the species' distribution, allowing them to persist and even thrive at the very edge of their geographic or landscape position distribution. Climate change scenarios suggest that as global temperature and precipitation regimes change, conditions in the center of a given plant species geographic range may become unsuitable, resulting in a decline of that particular species. However, edge plants may be somewhat more adaptable to the changing climatic conditions due to their former position at the edge of the species distribution. Therefore, these edge plant species individuals may serve two purposes: (1) ability to maintain plant community association and resist invasion by less desirable, non-native species and (2) use as potential breeding stock for that species which could then be used to support establishment and growth in a shifted climatic regime.

Recruitment of edge vegetation within training and testing ranges is a more or less passive process that requires little input, especially in more humid climates with diverse and productive plant communities like those at Fort Leonard Wood. Edge species recruitment can be accomplished most effectively on training ranges with desirable seed banks and/or adequate seed rain, often in areas near the edges of existing areas of established desirable vegetation. Indiangrass, in particular, can colonize areas following spring burns. Controlled spring burns at Fort Leonard Wood are currently used to remove existing vegetation and create conditions favorable for desirable vegetation establishment.

Timing of these burns can also influence the composition of edge vegetation recruitment. Spring burns favor native warm season grasses, while fall burns favor forb establishment. For a functional plant community, edge recruitment should be begin with native grasses until an adequate cover has been maintained, followed by fall burns until the forb component has reached a desirable level. After a desired community has been recruited, a somewhat staggered fire regime can be used to maintain the community. It is important to note that with the anticipated increases in both length of growing season and vegetative productivity associated with climate change, maintenance of controlled burning regimes (Figures 3-6 and 3-7) is of paramount importance for future training range sustainability.

Figure 3-6. Controlled spring burns at Fort Leonard Wood are currently used to remove existing vegetation and create conditions favorable for desirable vegetation establishment.

Figure 3-7. Native grasses, like Indian grass (*Sorghastrum nutans*), thrive with other grasses and forbs following prescribed burns.

3.6 Control of invasive plants

Invasive plant species can be a significant detriment to seeded vegetation. Successful invasive species often share traits that allow them to rapidly increase in abundance and exploit habitat openings (Dukes and Mooney 1999). A hotter, drier climate will likely result in resource pulses that favor invasive species, especially where dominant native species are suppressed by land disturbing activities (Dukes et al. 2011) like those associated with military training. Due to differences in growth strategies and biology, many invasive plants are not as resilient to training disturbance and/or provide an inferior vegetative cover which ultimately results in erosion and further degradation of the native plant community.

Currently, the most destructive invasive plant species at Fort Leonard Wood are crabgrass (*Digitaria* species), goosegrass (*Eleusine indica*), Johnsongrass (*Sorghum halepense*), Sericea lespedeza (*Lespedeza cuneata*) and spotted knapweed (*Centaurea bieberteinii*). Many of these species have shown positive response to increasing temperatures and atmospheric carbon dioxide concentrations (Polley et al. 2013) and would be expected to increase in abundance over the next 25-75 years. Fortunately, the efficacy of many currently used herbicides is not expected to be significantly impacted by a changing climate and will remain viable options for invasive species control. One of the most effective options for invasive plant control in newly seeded areas is to spray glyphosate before seeding, as this nonselective herbicide will remove all existing vegetation.

Crabgrass and goosegrass are most destructive in newly seeded and establishing vegetation (Figure 3-8). The most effective control for these grasses is usage of Plateau herbicide (imazapic). This herbicide works best as a pre-emergent, but can also be effective as a post-emergent herbicide if the weeds are still small in stature (see herbicide label for specifics). The benefit to using this herbicide is that most native warm season grasses are tolerant to this herbicide (with the notable exception being switchgrass [*Panicum virgatum*]). The drawback is that some forbs are intolerant and could be negatively impacted.

Figure 3-8. Without treatment, crabgrass and goosegrass are most destructive in newly seeded and establishing vegetation.

Spotted knapweed, Sericea lespedeza and Johnsongrass can also be detrimental to seeded and establishing vegetation, but because they have the propensity to invade established vegetation, they can slowly replace entire communities of desirable vegetation. Johnsongrass can also be effectively controlled using imazapic. Sericea lespedeza is most effectively controlled using Garlon (triclopyr) before flowering or Escort (metsulfuron) after flowering. Spotted knapweed is most effectively controlled using Transline (clopyralid) before flowering. Due to restrictions on pesticide use on DoD lands, as well as costs for purchasing and applying them, spot treatments of infested areas should be used to minimize usage and associated costs.

4 Summary

It is projected that the growing season at Fort Leonard Wood, MO will increase by 7 days by 2050, and by an additional 20 days by 2090. These increases, while seemingly insignificant now, will cause changes at Fort Leonard Wood over time. However, a number of adaptation strategies can be implemented at Fort Leonard Wood in the face of a changing climate to ensure that training and testing ranges, to enable that installation to continue to provide sustainable, realistic, and cost effective training opportunities for the warfighter well into the future:

- *Adaptive planning*. From a training range management perspective, one of the more important potential changes associated with longer growing seasons are increased fire risk and frequency as earlier springs. Many natural resources management activities such as firebreak management, emergency seeding, and mowing are time and weather dependent and have short windows of opportunity for completion. as part of each training event scheduled by individual units through range control, some mechanism for contributing to a dedicated “Green Fund” should be developed. Such a dedicated fund that could only be used for LRAM activities would partially eliminate the need for lengthy and contorted contracting actions that seldom meet the time and weather sensitive needs of LRAM activities designed to reduce risk. (See Section 3, p 7.)
- *Organic matter conservation*. Most training lands, including those at Fort Leonard Wood, are often highly eroded as a result of recurring and destructive training activities. The benefits of organic matter content to soils that are sandy textured, have poor water holding capacity, and/or are highly eroded or compacted are well known. As the climate becomes warmer with more frequent and severe droughts, the importance of maintaining or improving soil organic matter content becomes even more critical, and land management practices should be adapted to current conditions as they change. (See Section 3.1, p 8.)
- *Seed and species selection*. Selection of seed does not require significant alteration at present. However, some alternatives are provided for consideration for complementing existing mixes or replacing specific components. (See Section 3.2, p 10.)
- *Seeding practices*. A number of standard practices may be adapted for rehabilitation of damaged training ranges to adapt to changing climate conditions. (See Section 3.3, p 13.)

- *Recruitment of edge vegetation*. Recruitment of edge vegetation within training and testing ranges is a more or less passive process that requires little input, especially in more humid climates with diverse and productive plant communities like those at Fort Leonard Wood. Edge species recruitment can be accomplished most effectively on training ranges with desirable seed banks and/or adequate seed rain, often in areas near the edges of existing areas of established desirable vegetation. After a desired community has been recruited, a somewhat staggered fire regime can be used to maintain the community. With the anticipated increases in both length of growing season and vegetative productivity associated with climate change, maintenance of controlled burning regimes is of paramount importance for future training range sustainability. (See Section 3.5, p 16.)
- *Control of invasive plants.* Invasive plant species can be a significant detriment to seeded vegetation. A hotter, drier climate will likely result in resource pulses that favor invasive species. Fortunately, the efficacy of many currently used herbicides is not expected to be significantly impacted by a changing climate and will remain viable options for invasive species control. (See Section 3.6, p 19.)

References

Albrecht, K. A., and W. Goldstein. 1997. *Silphium perfoliatum*: A North American prairie plant with potential as a forage crop. *Proceedings of the International Grassland Congress*, Paper 1113, Winnipeg, Canada.

Busby, R. R., D. L. Gebhart, and H. A. Torbert. 2006. Effects of an uncomposted municipal waste processing by-product on prairie grass establishment. *Agronomy Journal* 98:1073-1080.

Dukes, J. S., and H. A. Mooney. 1999. Does global change increase the success of biological invaders? *Trends in Ecology and Evolution* 14:135-139.

Dukes, J. S., N. R. Chiariello, S. R. Loarie, and C. B. Field. 2011. Strong response of an invasive plant species (*Centaurea solstitialis L.*) to global environmental changes. *Ecological Applications* 21:1887-1894.

Guisquiani, P. L., M. Pagliai, G. Gigliotti, D. Businelli, and A. Benetti. 1995. Urban waste compost: Effects on physical, chemical, and biological soil properties. *Journal of Environmental Quality* 24:175-182.

Mamo, M., T. R. Halbach, and C. J. Rosen. 1998. *Utilization of Municipal Solid Waste Compost for Crop Production*. University of Minnesota Extension Service. Report FO-7083-GO 1998.

Maughan, M. W. 2011. *Evaluation of Switchgrass, M. X giganteus, and Sorghum as Biomass Crops: Effects of Environment and Field Management Practices*. Ph.D. Dissertation, University of Illinois, Urbana.

McConnell, D. B., A. Shiralipour, and W. H. Smith. 1993. Compost application improves soil properties. *Biocycle*. April 1993: 61-63.

McGraw, R. L., F. W. Shockley, and T. K. Elam. 2003. Effects of temperature on germination of 10 native legume species. *Native Plants Journal* Spring 2003:5-9.

Minnesota Department of Transportation (MN DOT). 2005. *Standard Specifications for Construction*.

Minnesota Department of Transportation (MN DOT). 2007. *Seeding Manual*.

Morrison, J. 2009. Hay and pasture. In *Illinois Agronomy Handbook*. Pubs Plus, University of Illinois, Urbana, pp 65-81.

Pagliai, M., and L. Vittori-Antisari. 1993. Influence of waste organic matter on soil micro and macrostructure. *Bioresource Technology* 43:205-213.

Pathak, T. B., K. G. Hubbard, and M. Shulski. 2012. *Soil Temperature: A Guide to Planting Agronomic and Horticulture Crops in Nebraska*. University of Nebraska-Lincoln Extension Guide g2122. Lincoln, NE.

Pechony, O., and D. T. Shindell. 2010. Driving forces of global wildfires over the past millennium and the forthcoming century. *Proceeding of the National Academy of Sciences of the United States of America* 107:19167-19170.

Polley, H. W., D. D. Briske, J. A. Morgan, K. Wolter, D. W. Bailey, and J. R. Brown. 2013. Climate change and North American rangelands: Trends, projections, and implications. *Rangeland Ecology and Management* 66:493-511.

Seepaul, R., B. Macoon, K. R. Reddy, and B. Baldwin. 2011. Switchgrass (*Panicum virgatum* L.) intraspecific variation and thermotolerance classification using *in vitro* seed germination assay. *American Journal of Plant Sciences* 2:134-147.

Stanford, G. 1990. *Silphium perfoliatum* (cup-plant) as a new forage. *Proceedings of the Twelfth North American Prairie Conference, Cedar Falls, IA*, pp. 33-37.

Turner, M. S., G. A. Clark, C. D. Stanley, and A. G. Smajstrla. 1994. Physical characteristics of a sandy soil amended with municipal solid waste compost. *Soil and Crop Science Society of Florida Proceedings* 53:24-26.

Undersander, D. H., L. H. Smith, A. R. Kaminski, K. A. Delling, and J. D. Doll. 1990. *Alternative Field Crops Manual*. Madison, WI: University of Wisconsin Cooperative Extension.

U.S. Department of Defense (DoD). 2013. Department of Defense Base Structure Report – Fiscal Year 2014 Baseline: A Summary of Real Property Inventory. Washington, DC: DoD.

Watts, D. B., F. J. Arriaga, H. A. Torbert, D. L. Gebhart, and R. R. Busby. 2012a. Ecosystem biomass, carbon, and nitrogen five years after restoration with municipal solid waste. *Agronomy Journal* 104:1305-1311.

Watts, D. B., F. J. Arriaga, H. A. Torbert, R. R. Busby, and D. L. Gebhart. 2012b. Non-composted municipal solid waste by-product influences soil and plant nutrients five years after soil reclamation. *Soil Science* 177:480-489.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2003. Warming and earlier spring increases in Western US wildfire activity. *Science* 313:940-943.

Wisconsin Department of Transportation (WI DOT). 2009a. *Construction and Materials Manual*.

Wisconsin Department of Transportation (WI DOT). 2012. *Standard Specificatons*.

Zhang, H., K. H. Hartge, and H. Ringe. 1997. Effectiveness of organic matter incorporation in reducing soil compatibility. *Soil Science Society of America Journal* 61:239-245.

Acronyms and Abbreviations

Term	Definition
ANSI	American National Standards Institute
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
DoD	U.S. Department of Defense
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
GCM	Global Climate Model
LRAM	Land Rehabilitation and Maintenance
MIM	Maneuver Impact Mile
MIPR	Military Interdepartmental Purchase Request
NSN	National Supply Number
OMB	Office of Management and Budget
PAIO	Plans, Analysis, and Integration Office
SAR	Same As Report
SF	Standard Form
TES	Threatened and Endangered Species

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
06-07-2016

2. REPORT TYPE
Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
Adaptation Strategies for Training Lands and Ranges at Fort Leonard Wood, MO

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT

6. AUTHOR(S)
Dick L. Gebhart, Ryan R. Busby, Andrew M. Hamblin, Annette L. Stumpf, and Susan J. Bevelheimer

5d. PROJECT NUMBER
MIPR

5e. TASK NUMBER

5f. WORK UNIT NUMBER
10599341

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005,
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-16-9

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Garrison Fort Leonard Wood
Plans, Analysis, and Integration Office (PAIO)
Fort Leonard Wood, MO 65473

10. SPONSOR/MONITOR'S ACRONYM(S)
PAIO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
In the United States and its territories, the Department of Army manages approximately 11 million acres of land for military use. The repeated and consumptive use of these lands for military training and testing activities, which is unique to the U.S. Department of Defense (DoD), creates a significant land management challenge. Superimposed upon these types of disturbance-related impacts are climate change scenarios that predict warming and greater climatic variability for the foreseeable future, including more frequent and severe droughts and intense storm events. This work identified and described several key planning and management activities that can be implemented in the face of a changing climate to ensure that training and testing ranges at Fort Leonard Wood, MO will continue to provide sustainable, realistic, and cost effective training opportunities for the warfighter well into the future.

15. SUBJECT TERMS
Fort Leonard Wood (Mo.), Military bases, Bombing and gunnery ranges, Climatic changes, Revegetation, Invasive plants--Biological control

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	34	